EVALUATING SUCCESSES IN PASSIVE TREATMENT AT SEQUATCHIE VALLEY COAL CORPORATION IN EAST CENTRAL TENNESSEE[1]

by

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Abstract: Passive treatment systems can be a cost-effective method of treating Acid Rock Drainage (ARD) at active mine areas, coal mine reclamation areas, and Abandoned Mine Lands (AML). However, passive treatment of ARD is a relatively new science. Some of the longest running systems have approximately two decades of information. Therefore, it is important to carefully evaluate existing passive treatment systems data to develop reliable predictive models for operation and maintenance. Systems utilizing Anoxic Limestone Drains (ALDs), settling ponds, and wetlands are effective passive treatment systems given acceptable ARD chemistry conditions. Typically, ALDs impart alkalinity to the ARD, settling ponds provide oxidation and storage space for the majority of oxidized metals, and wetlands provide final polishing prior to discharge. Sequatchie Valley Coal Corporation (SVCC) installed an ALD containing approximately 5,000 tons of limestone in 1995 in east central Tennessee. Two pond cells provide storage for oxidized metals and two wetlands cells provide final polishing. The passive treatment system has been monitored on a regular basis since construction. Evaluation of these data assists in the projections of passive treatment system longevity and provides the basis for determining long-term operation and maintenance needs.

Additional Key Words: anoxic limestone drain, ALD, passive treatment system

Introduction

The Sequatchie Valley Coal Corporation (SVCC) mine reclamation site is approximately 45 miles northwest of Chattanooga, Tennessee. During the active mining phase from 1978 to the mid-1980's, the SVCC single seam, area surface mine affected approximately 175 acres. A dragline operated in pits oriented along strike which progressed down dip at a site known as Reclamation Area 1 (RA1). Land reclamation at RA1 was completed by the mid 1980's, although water discharges requiring chemical treatment began to appear as groundwater elevations rose and ARD formed. ARD from these seeps was treated by conventional chemical treatment using sodium hydroxide, aeration, and sediment basins.

SVCC subsequently assessed the applicability of an Anoxic Limestone Drain (ALD) and constructed wetlands at RA1 (Hedin and Massey, 1995). ALDs are used to increase alkalinity concentrations in water through dissolution of limestone (Turner and McCoy, 1990). An ALD consists of an area of buried limestone placed in a manner to allow water to flow by gravity through the porous limestone bed in the absence of oxygen. ALDs are often the passive alkalinity addition technique of choice due to relatively low capital and operating costs. However, ALDs are not appropriate for all water chemistry conditions. The presence of dissolved oxygen and/or ferric iron may limit limestone dissolution due to armoring by ferric hydroxide. In addition, the presence of aluminum in the source water will precipitate aluminum hydroxides which may clog the ALD flow paths. These water chemistry limiting factors can be assessed through the careful evaluation of water quality analyses.

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Assessing the Applicability of an ALD

Cubitainer testing (Watzlaf and Hedin, 1993) was initiated in 1993 to estimate alkalinity likely to be generated at RA1. Alkalinity increased from approximately 140 mg/l to over 340 mg/l in the first 48 hours of the cubitainer test (Schmidt, et. al., 1996). Based on cubitainer results, it was expected that an ALD at RA1 would generate alkalinity of a similar magnitude and indicated favorable conditions existed for utilization of an ALD.

Cubitainer tests were followed by simulation of anticipated variable flow conditions using a 65-ton test ALD constructed in January 1995. After an initial flushing, water exiting the test ALD contained alkalinity concentrations of approximately 360 mg/L which stabilized at approximately 320 mg/L after a few months of operation at a flow rate of approximately 5 gpm. Flow rates were gradually increased up to 20 gpm which is proportionally greater than the maximum expected flow to the full-scale ALD. The pilot-scale test covered the full range of expected conditions for the proposed full-scale ALD. The critical condition occurred at a flow rate of 15 gpm when alkalinity concentrations had been reduced to approximately 265 ppm and the water exiting the test ALD became net acidic.

Full-Scale ALD Design

After it was concluded that an ALD was an applicable treatment method for groundwater seepage at RA1, the full-scale design and construction of a 5,000-ton ALD was completed near the end of 1995. The source water to be treated, based on samples of the groundwater seeps, was approximately 5.6 pH, 117 mg/L iron (all ferrous), 42 mg/L manganese, and <1.0 aluminum. Hydrologic modeling and measurement of groundwater seepage rates indicated the average anticipated design flow should be 200 gpm.

The full-scale ALD design included excavation of the backfilled highwall at the low point of the coal structure to direct groundwater flow to the 5,000-ton ALD and settling basins. Groundwater elevations were then controlled by the ALD located approximately 10 feet lower than the previous groundwater elevation.

Based on scientific and economic factors, the ALD was conservatively designed for a minimum ten-year life at full alkalinity production. The passive treatment design allowed for complete evaluation of the system and provided the ability to add limestone to the ALD without requiring a complete replacement of the ALD. In the future, soil materials and the liner could be removed from above the remaining limestone, additional limestone could be added, and the liner and soil materials could be replaced at a cost much less than original ALD construction costs. It was also considered that the ALD system may last much longer than ten years due to reduced acidity of the ARD over time as acid materials are dissolved and the total volume of acid bearing rock available for dissolution is reduced.

Settling basins were sized considering surface area and volume from United States Bureau of Mines criteria (Hedin, et al., 1994). Based on a flow rate of 200 gallons per minute, the minimum pond size of 1.5 acres was determined. Actual configuration included a two pond system with 2.4 acres of surface area and 16.3 acre-feet of volume. Basin A had a volume of 3.7 acre-feet (approximately 6,000 cubic yards) and Basin B had a volume of 12.6 acre-feet (approximately 20,000 cubic yards). The design retention time of the basin system at a flow rate of 200 gallons per minute was roughly 11 days, assuming sixty percent effective capacity. Optional wetlands with a total surface area of two acres were also included in the initial design for final polishing.

Evaluation of Passive Treatment System Performance

Flow, alkalinity, and pH field measurements (Table 1) were taken on a frequent basis after initial ALD installation.

The ALD alkalinity production rate is consistent with the rates estimated using the cubitainer and the test ALD. However, the flow rates were higher than predicted (Table 1) due partially to higher flow during the spring period. The longer term average flow rate from 1996 through 2000 was approximately 266 gpm. This rate is still about 1/3 higher than the design flow rate of 200 gpm.

Following the 5,000-ton ALD, Basin A, and Basin B, the treated water then flowed through a long channel in the location of the proposed wetlands prior to discharge to the receiving stream. The wetlands were added in the period late 1996 to early 1997. The final NPDES discharge monitoring point is located where the treated water discharges to the receiving stream. Table 2 provides some recent water quality data at the NPDES discharge point.

Table 1. Initial ALD flow, pH, and alkalinity production rates

DATE	FLOW (GPM)	pH	ALKALINITY (mg/L)
2/1/96	319	6.5	345
2/9/96	554	6.5	295
2/16/96	385	6.4	330
2/23/96	289	6.7	350
3/4/96	246	6.5	340
3/8/96	335	6.3	320
3/22/96	304	6.3	330
4/4/96	351	6.5	325
4/12/96	335	6.3	330
4/18/96	304	6.3	330
4/26/96	335	6.2	330
5/2/96	335	6.2	310
5/12/96	330	6.2	330
5/17/96	335	6.2	330
5/24/96	304	6.4	345
5/31/96	275	6.3	330
6/7/96	233	6.4	330
6/14/96	207	6.2	300
6/21/96	195	6.3	330
AVERAGE	**314**	**6.4**	**328**

The passive treatment system has achieved remarkable performance for both the ALD alkalinity generation rate and the pond/wetland system for capture of oxidized metals (Table 1 and Table 2). Throughout the passive treatment system life, NPDES permit limits, including biotoxicity testing limits, were met with few exceptions.

The ALD alkalinity generation rate is one of the highest reported for a standard ALD installation. The average alkalinity generation rate for the period 1996 through 2000 is approximately 325 mg/L with the average flow rate of 266 gpm. This alkalinity generation rate at the average flow rate indicates limestone dissolution occurred at a rate of approximately 190 tons per year. This means that approximately 950 tons of limestone has been dissolved and 4,050 tons of limestone remain in the ALD.

The critical condition in the 65 ton test ALD occurred at a flow rate of 15 gpm (4.3 tons per gpm) when alkalinity concentrations had been reduced to approximately 265 mg/L and the water exiting the test ALD became net acidic. Applying this logic to the

Table 2. Passive system NPDES discharge analytical data

DATE	FLOW (GPM)	pH	SETTLEABLE SOLIDS (mg/L)	IRON (mg/L)
07/14/99	351	6.9	<0.1	0.10
08/11/99	233	6.9	<0.1	0.26
08/31/99	183	7.2	<0.1	0.43
11/10/99	139	6.5	<0.1	0.27
01/12/00	233	7.1	<0.1	0.16
03/08/00	149	6.9	<0.1	0.32
05/10/00	207	6.8	<0.1	0.19
07/12/00		6.4	<0.1	0.52
09/13/00	101	8.0	<0.1	0.18
11/08/00	119	6.7	<0.1	0.16
AVERAGE	**191**		**<0.1**	**0.26**

full-scale ton ALD, the critical condition would occur at a remaining tonnage of 1,150 tons at the average flow rate of 266 gpm and at a tonnage of 2,600 tons at the maximum flow rate of 600 gpm. These data indicate that the ALD should continue to produce water with alkalinity greater than or equal to acidity for over seven additional years (until 2007) even when high flow periods (up to 600 gpm) are encountered. These data also indicate that the ALD should continue to produce water with alkalinity greater than or equal to acidity for over 15 additional years (through 2015) for flows up to 266 gpm. This data analysis confirms that the 10 year design was, in fact, conservative. The analysis indicates that it is more likely that the ALD would last for up to 12 years, even at higher than anticipated average and peak flows.

In late January 1996, sampling was conducted to evaluate the performance of the entire system when the flow rate was 335 gpm. Resulting data is shown on Table 3.

These data collected shortly after construction indicated that over 50% of the iron was captured in Basin A, over 80% had been removed prior to discharge from Basin B, and nearly 95% was removed prior to discharge from the channel. It was anticipated that the efficiency would increase when vegetation of the basin embankments occurred and the system had stabilized. Therefore, additional total system evaluations were planned for mid-1996.

An additional system evaluation sample was collected in July 1996 when the flow rate was approximately 120 gpm. The results are included on Table 4.

These data indicate that the system worked very effectively with approximately 70% iron removal in Basin A and over 99% removal prior to discharge from Basin B. After review and consideration of all data, it was determined that the optional wetlands should be constructed in order to assure optimal treatment during higher than anticipated flow periods. Two wetland cells were subsequently constructed during late 1996 to early 1997. The total surface area was approximately two acres with a variable depth. Some deeper pockets of up to 4 feet were included with most of the wetland area at an average depth of 1.5 feet.

An additional system performance sample was collected August 2000 when the system was flowing at a rate of 101 gpm. The analytical results are shown on Table 5.

These data indicate that the system continued to worked very effectively with approximately 70% iron

Table 3. January 1996 analytical data

	ALKALINITY (mg/L)	IRON (total) (mg/L)	IRON (tons/year)	pH
ALD	330	97.3	71.7	6.4
BASIN A	240	52.2	38.5	6.7
BASIN B	180	18.5	13.6	6.9
CHANNEL	160	6.1	4.5	7.1

Table 4. July 1996 analytical data

	ALKALINITY (mg/L)	IRON (total) (mg/L)	IRON (tons/year)	pH
ALD	345	138	36.4	6.2
BASIN A	175	42.7	11.3	6.5
BASIN B	125	0.19	0.05	7.1

Table 5. August 2000 analytical data

	ALKALINITY (mg/L)	IRON (total) (mg/L)	MANGANESE (mg/L)	pH
ALD	185*	74.0	30.5	6.3
BASIN A	170*	23.8	32.8	6.2
BASIN B	175*	0.52	27.2	7.0
WETLAND A	120*	0.11	13.7	7.0
WETLAND B	100*	0.09	1.40	7.1
* Based on laboratory data, prior alkalinity results were done on site				

removal in Basin A and over 99% removal prior to discharge from Basin B. Data from the final effluent discharge location for these two data sets are fairly representative of results at the final discharge point for the entire sampling period 1996 through 2000. Based on the detailed treatment efficiency samples collected July 1996 and August 2000, prediction of iron sludge collection and accumulation can be made from which maintenance needs can be estimated based on the following assumptions:

1) 266 gpm average flow rate;
2) 79 mg/L average iron;
3) 70% of the iron load is retained in Basin A;
4) 30% of the iron is retained in Basin B; and
5) iron oxide sludge volume is 0.10 g Fe/cc sludge (value for settled SVCC iron sludge measured by Hedin in 1996).

Based on these assumptions, the sludge volume and new basin volumes can be estimated. In the five years since passive treatment system construction (time period 1996 through 2000), approximately 2,700 cubic yards of iron oxide sludge was captured in the Basin A and Basin B system. Estimates of sludge retention by basin are shown on Table 6.

Table 6. Iron oxide sludge retention estimates 1996 through 2000

	JANUARY 1996 CAPACITY CUBIC YARDS	DECEMBER 2000 CAPACITY CUBIC YARDS	PERCENT CAPACITY REMAINING
BASIN A	6,000	4,100	68%
BASIN B	20,000	19,200	96%
TOTAL	26,000	23,300	90%

These estimates indicate that 90% of the original basin system capacity remains after a 5-year period. However, due to the characteristics of iron precipitation dynamics within the basin system, Basin A is filling with iron oxide sludge more quickly. Typically, for erosion and sediment control, basins are recommended to be cleaned out when the sediment level reaches ½ of the original design capacity. Applying this rule of thumb to the passive treatment system at RA1 results in Basin A being cleaned after approximately 8 years of use and Basin B being cleaned after approximately 60 years of assuming the same average flow rate, iron concentration, and iron retention dynamics.

SVCC is considering the final disposition of the iron oxide sludge. If possible, it is desired to recover this sludge for use as a pigment. If this is not feasible, other options will be evaluated, including disposal at approved on-site locations.

The wetlands were designed to provide final polishing of the treated effluent. The quantity of oxidized metals collected in the wetlands is very low compared to the basins. It is projected that these wetlands may never require cleaning. However, as build up occurs, it may be necessary to raise the discharge elevations and ponded water elevations. This factor was considered in the original design and may occur without the need to raise the embankment of the wetlands.

Conclusions

Sequatchie Valley Coal Corporation (SVCC) constructed a 5,000-ton ALD in late 1995. The performance of the passive treatment system has been remarkable with an alkalinity generation rates of approximately 325 mg/L. The basins have effectively collected oxidized iron, and the wetlands have provided final filtering of the treated water. Throughout the passive treatment system life, NPDES permit limits, including biotoxicity testing limits, were met with few exceptions.

Test ALD information was applied to the full-scale ALD to project longevity and rehabilitation needs. The ALD should operate effectively and handle even maximum flow rates until 2007 (12-year life). Rehabilitation may simply include addition of limestone to the ALD.

Periodic evaluation of individual cells provides a basis for determinating potential clean out of iron oxide sludge. Assuming that the basins should be cleaned when half full with sludge, Basin A should be cleaned after 8 years (2003) and Basin B should be cleaned after 60 years (2055). This clean out schedule is another important component for determination of long-term operation and maintenance needs and the ability to estimate long-term operation and maintenance costs. SVCC is also continuing to evaluate the final disposition of the removed sludge. Use of iron oxide sludge as a pigment is the desired alternative. However, if this is not feasible, other options will be considered including on-site disposal at approved locations.

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